FROM INTERSTELLAR DUST TO COMETS

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The bulk and microstructure of comet nuclei are derived from the morphological structure and chemical composition of submicron sized interstellar dust grains which have undergone cold aggregation in the pre-solar nebula (Greenberg 1982a, 1986a) because the volatile molecule S_2 may be traced back to the photochemical evolution of the interstellar dust (Grim and Greenberg, 1987) and because the CH_4/H_2O ratio is inconsistent with comet condensation of solar system volatiles (Larson et al. 1988).

The evolutionary picture of dust which is emerging is a cyclic one in which the particles, before being destroyed or going into solar system bodies, find themselves during their 5 billion year lifetime alternately in diffuse clouds and in molecular clouds (Greenberg, 1982b, Greenberg, 1986, Schutte, 1988). A small silicate core captured within a molecular cloud accretes various ices and gradually builds up an inner mantle of organic refractory material which has been produced by photoprocessing of the volatile ices. Because of the cyclic evolution the organic refractory mantle on a grain is not a homogeneous substance but rather layered like the rings of a tree trunk in which the innermost layers have been the most irradiated and the outermost layer in the most recent molecular cloud phase is first generation organic refractory which is surrounded finally by lightly photoprocessed ices of which H_2O is the dominant component. Since further photoprocessing of organics leads to a greater and greater depletion of O, N, and H, the innermost layers are the most "carbonized" and the most non-volatile (See Fig. 2 insert).

Clumps of grains form, and then clumps of clumps, and so on, until finally we reach the size of the comet nucleus. Comparing such interstellar dust aggregates with meteors leads to a packing factor of 0.2; (See Fig. 2a).

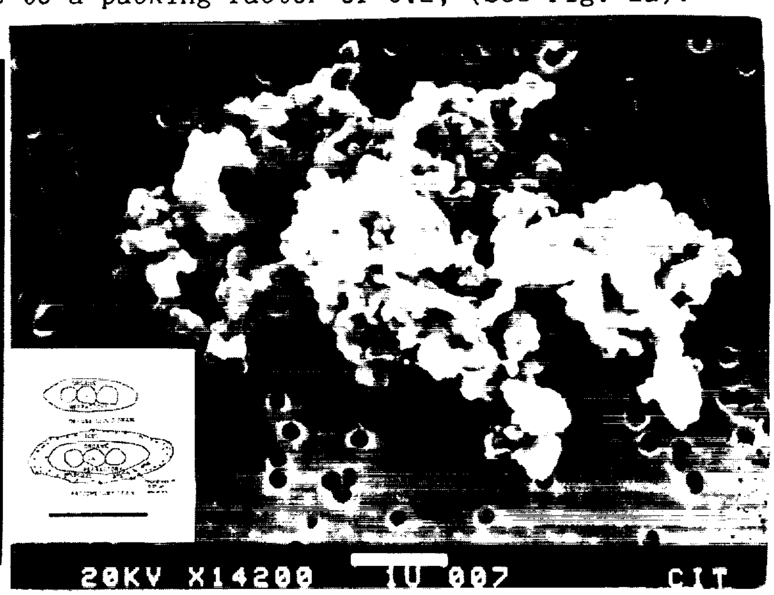

Fig. 2a: A piece of a fluffy comet: Model of an aggregate of 100 average interstellar dust particles with a packing factor of about 0.2 (80% empty space), a mean mass density of 0.28 gm cm^{-3}, and an aggregate diameter of 5 μm.

Fig.2b: A highly porous chondritic IDP. Note that the bird's nest particle (Fig.2a), the IDP (Fig.2b) and average interstellar core-particle (Fig.2b insert) are equally scaled to 1 μm.

Kissel and Krueger (1987) have derived a comet dust ratio of organics to silicate mass of $m_{OR}/m_{sil} \approx 1:2$ which, not surprisingly, is less than that in the interstellar dust because of the expected evaporation of the less refractory organics from the comet dust at solar system temperatures.

The 3.4 μm and 10 μm excess emissions in comet dust provide evidence not only for the basic chemical ingredients - as given in the mass spectra - but also for the morphological structure (Greenberg, Zhao and Hage, 1989). It turns out that pure silicates no matter how small do not achieve high enough temperatures to produce the observed 10 μm emission. Absorbing organic refractory mantles - such as those on interstellar silicate cores - are absolutely required to raise the compound grain temperatures high enough to make the 10 μm peak observable. Furthermore, the temperature constraint leads to a most probable silicate core radius ~ 0.05 μm and a mantle thickness $\gtrsim$ 0.02 μm. i.e. an organic to silicate mass ratio $m_{OR}/m_{Sil} \approx 0.9$ which, within the uncertainties, is like that deduced from comet dust mass spectra. It is only by considering these 10^{-13} g particles to be in fluffy aggregates that the integrated fluxes come into reasonable resemblance to the particle impact detector data (McDonnell et al., 1987).

Interplanetary dust particles which are within 1 AU scatter visible light much more effectively than those which are beyond 1 AU. While those which are farther out are more effective emitters of infrared radiation. The radial decrease of the albedo of the zodiacal light particles could be produced by a decrease in material density, just as the albedo of cometary dust is decreased because of its fluffiness. The interplanetary particle probe results of Pioneer 10/11 were also interpreted in terms of a radial decrease of particle density (Fechtig, 1984). Additional indications for the cometary to interplanetary dust evolution may be seen in the lower density of meteors whose aphelion distances are beyond 5.4 AU as compared with those which spend more time closer to the sun (Verniani, 1973).

Although the mean density of the chondritic porous IDP's is low it is much higher than the initial cometary dust. What we see in Fig. 2b is an aggregate of more or less spherical particles of about 0.1 μ diameter whose infrared signature is that of silicates. When the interstellar dust is scaled like the IDP we see how its silicate core segments - which are hidden in the bird's nest model (Fig. 2a) - are like the silicates in the IDP. While the organic mantles are not "seen" in the IDP electron micrographs they become immediately apparent with Raman spectroscopy (Wopenka, 1988). It appears that every silicate particle in a porous IDP is covered by some organic mantle.

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